Spatio-temporal variation of groundwater discharge and related water quality in the nearshore Shiraho Reef, Ishigaki Island

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In south Shiraho Reef (Ishigaki Island, Okinawa), submarine groundwater discharge (SGD) has been found to be significant, considering that the plume from Todoroki River does not usually travel towards the south. However, SGD in the coral reef, the factors giving rise to its variation, and its influence on nutrient concentration and primary productivity, particularly in nearshore reef areas, have not been thoroughly investigated. We utilized radon (222Rn) tracing in tandem with water quality monitoring through data-logging instruments (e.g., salinometer, in situ nutrient analyzer, and submersible fluorometer) and nutrient analysis of water samples to investigate the spatial and temporal variations of SGD. In August and September 2008, 222Rn in nearshore Shiraho Reef ranged from 60 to 1300 Bq/m^3. Groundwater flux during low tide was estimated from continuous hourly 222Rn measurements at a monitoring station to be around 3-5 cm/hr, occasionally reaching 7-8 cm/hr. Assuming a 100 m^2 foreshore discharge area (as monitored by the station), this translates to 0.00075-0.0012 m^3/s. Higher rates of groundwater discharge were associated with higher nitrate concentrations. Nitrate-N concentrations ranged from 0.6 to 1.4 mg/l (42.9-100 umol/L) during low tides, compared to 0.09-0.26 mg/L (6.4-18.6 umol/L) during high tides. Groundwater discharge rates and, consequently, $NO_3{}^-$-N concentration were higher during spring tide than during neap tide due to stronger tidal pumping during spring tide. However, this is also influenced by groundwater recharge in the adjacent lands. One to two days after the typhoon on 28 September 2008, more groundwater was discharged into the reef as evidenced by the drastic decline in nearshore salinity. 222Rn concentration of samples taken from wells in Todoroki watershed indicated enrichment of radon, particularly after rainfall events. Results of sediment equilibration experiments showed that bottom sediments did not contribute (via molecular diffusion) significant amounts of 222Rn to the overlying water. All these indicate that the elevated 222Rn activities were due to largely to groundwater advection. The increased nutrient levels increased the total Chl-a concentration from around 0.5ug/L to 1.5ug/L. Diatoms and bluegreen microalgae (cyanobacteria) dominated, both of which exhibited an increasing trend in concentration. However, the percentage contribution of diatoms decreased from 85% to 70% while that of cyanobacteria increased from 12% to 27%. In January 2009, 222Rn activities in the watershed wells and nearshore waters were noticeably lower. Estimated groundwater flux based on 222Rn monitoring at three stations only reached a maximum of about 4 cm/hr on the average. Analysis of nearshore samples during low tide and early flood tide showed that the central and southernmost portion of nearshore Shiraho Reef have the highest rates of groundwater discharge.